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2013

Faculty of Economics and Business Administration

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Research Memorandum 2013-32

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User-Centric SDI Framework Applied to Historical and Heritage European Landscape Research.*

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Abstract

Spatial scientific research has increasingly become multi disciplinary. The urge of different disciplines to share disciplinary knowledge and information has increased. However, not many Spatial Data Infrastructures (SDIs) have succeeded in facilitating the needs of these multidisciplinary research communities. The article presented offers a methodological framework to develop a user centric SDI and applies it to the community that researches the history and heritage of urban and rural landscapes in the Netherlands. It demonstrates how users' objectives and Geospatial Information literacy can be determined and can inform the conceptual and technological architecture of a user centric SDI. The architecture of the historical and heritage landscape SDI focuses on developing a user friendly dashboard, placed at the heart of the SDI and developed in close collaboration with the users. The framework and architecture presented functions as an example for other third generation SDIs and forms an anchor point for developing historical and heritage landscape SDIs in Europe.

Keywords: Spatial Data Infrastructure, hertiage, history, European landscape research, third generation SDI, user centric.

The research was financed by The Netherlands Organisation for Scientific Research (NWO) as pilot study for the needs of an SDI for historical and heritage landscape research (file: 380-57-001).

1. INTRODUCTION

In the past decades, spatial scientific research has increasingly become multi disciplinary. The need to share spatial data and exchange information produced by different participants has become a necessary feature for spatial oriented scholars. Spatial data infrastructures (SDI) have been developed to facilitate this. These user focused infrastructures are referred to as third generation SDI. As stated by Hennig and Belgiu (2011), the biggest challenge to come to a truly user centric SDI is to facilitate the dynamic demands of users. They argue that the way forward is *not* to let SDI-experts observe the field and design and implement an infrastructure based on their knowledge on the possibilities of SDIs, but to involve the end users throughout the design and implementation and evaluation process. As they argue, "Users' involvement ensures identification and capture of their still unfulfilled and unknown requirements" (Hennig and Belgiu 2011, p.40). This involvement should focus on identifying the data and services required by the users based on their specific application areas. More specifically, the information that users need to produce in order to conduct their core tasks and the Geospatial Information (GI) skills they themselves possess to transform the data into useful information for their work, should inform the data and services integrated in the SDI. Complementary to Hennig and Belgiu's viewpoint, other SDI literature stresses the importance of strong leadership. These scholars are not advocating a traditional top-down approach, but argue that user involvement should be carefully coordinated by a party with expertise of technical and organisational SDI components (Craglia and Annoni 2007).

This article develops and demonstrates a generic approach for achieving such a symbiosis between top-down and bottom-up development, using a prominent and growing field of European research and policy dedicated to the understanding and management of historical and heritage landscapes. What makes this research community highly interesting in the discussion on how and why to develop third generation SDIs is that it has a heterogeneous body of users with varying demands and varying degrees of Geospatial Information (GI) literacy. Furthermore it distinguishes itself from other SDIs by being focussed on time, going beyond national borders and having a high demand to valorise research results to a broader public.

Section two elaborates on the problem definition and outlines the generic approach. Sections three and four apply the first stage of this approach to the mentioned research and policy domain and propose an SDI architecture informed by the found user requirements. The final sections suggest how the second stage of the approach may be implemented to enhance the initial SDI, how the overall approach can be applied to other domains and what steps need to be taken for its further enhancement in aid of user-centric SDI development.

2. ANALYTICAL FRAMEWORK

The core function of a Spatial Data Infrastructure is to enable users, beyond the level of a single institute or organisation, to share geospatial information more easily. The first thoughts and initiatives to develop SDIs were formulated during the 1990s (Rajabifard et al 2002). Over the past two decades, this has resulted in numerous initiatives for SDI development (e.g. Nature-SDIplus and EuroGEOSS). Together these have generated a base of knowledge and expertise on how to share geospatial information from a technological and organisational perspective (Crompvoets et al 2008). First generation SDIs were focused on producing, collecting and centralising spatial information for a small group of GI-specialists (Rajabifard 2002, Masser 1998, Hennig and Belgui 2011, Craglia and Annoni 2007). These clearinghouses product-based SDI initiatives were mainly developed by and for government agencies. Although aimed at a small group of specialists, first generation SDIs produced valuable insights regarding organisational and technological building blocks for future SDIs with wider scope. Second generation SDIs occurred around 2000 and were more focused on the management of information assets by linking metadata, data and people (Craglia and Annoni 2007, Rajabifard et al 2006). The philosophy of these initiatives was to facilitate data sharing and data re-use. Thus, more than previous initiatives, second generation SDIs focused on the users and the services they required to use available data. Still, the technical and organisational requirements of the SDI were determined top-down by SDI experts. Although some debate on what a third generation SDI is exists (Masó et al 2012), this article approaches third generation SDIs as the step through which the users themselves play an active role in setting the requirements, albeit with an important coordinating role by SDI experts. Furthermore, these latest SDIs serve a more heterogeneous body of users, with varying demands and varying degrees of GI-literacy. This important change is obviously stimulated by technological improvements of the internet and the availability of more advanced geospatial technologies in society (e.g. cloud computing, interactive maps in internet browsers, GPS enabled smart phones etc.). These improvements have, *finally*, made it possible to actually serve users, including non-GI-experts, effectively, thus placing them at the heart of the SDI.

Given the evolving character of SDIs, it is not surprising that a variety of SDI definitions exist (e.g. Masser 1998, Rajabifard et al 2002). Still, a number of common features can be identified. A thorough analysis of 28 definitions by Hendriks et al (2012), led them to distinguish between objectives and components. They found that users are often included as one of the components. However, to come to a method for user centric SDI development, we propose to the give the users a prominent role by separating them from the components and connect the users instead to the objectives and the GI skills. The users' information needs (objectives) and skills (GI literacy) together inform which data and services they require from the SDI (organisational and technical components). The relationship between these elements is displayed in figure 1.

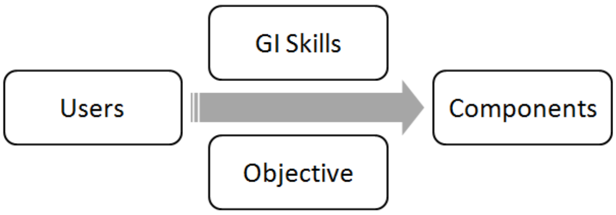


Figure 1 Features in a user centric SDI

For example, a user with basic GI skills who wishes to compare a historical map with the current topography needs to be able to download the historical map and georeference it in a desktop GIS, whereas a user with hardly any GI skills would only be capable of this comparison with already georeferenced material available in a webviewer. Of course, it would be an option to train the latter user and improve his GI skills so he can conduct this task in a desktop GIS. However, especially in past oriented disciplines, many potential SDI users are not willing or capable to do so and would at most be able to use easy-to-use processing services (Boonstra 2009).

The analytical framework proposed in this article for the development of third generation user-centric SDIs is derived from the elements described above (figure 1). The following sub-sections will explain how the objectives and GI-literacy can be determined and how the outcomes of the analyses inform which organisational and technical components should be implemented as part of the SDI. It is important to stress that this process should be conducted cyclically and that the SDI experts should collaborate closely with the users at each stage and in each cycle of the SDI development.

Initially, this collaboration will focus on what the researchers anticipate they wish to achieve and which services the SDI experts could offer. During the process the emphasis will shift to the researchers' experience of services developed in aid of their actual research. This structure guarantees that the users play a central and dynamic role (as stressed by Hennig and Belgui 2011), while at the same time the SDI experts can put their expertise to best use (as stressed by Craglia and Annoni 2007), hence that the users' needs can be fine-tuned and the performance of the SDI optimised in the course of design and implementation of the infrastructure.

2.1. Objectives

To make the user objectives a workable input for the SDI development it is necessary to translate their specific objectives into information objectives. Objectives such as “reconstructing settlement patterns in region x between era y and z” or “evaluating the status of listed building type x across Europe” should be translated into the types of information required to achieve idem. It is helpful to use example projects to make this translation, with the aim to identify the information needs of the research and policy that they represent rather than the needs unique to the project. To aid this analysis, we have formulated a list of common geo-information characteristics (table 1). This list is not meant to be exhaustive, but acts as a starting point for the analysis. Determining the GI characteristics of data and information required for the SDI is an ongoing process since it largely depends on the project at hand. An initial assessment of the researchers’ anticipated needs helps to determine the initial architecture of the SDI. Follow-up assessments conducted with the help of the initial SDI result in a refinement of data and services needed to meet the researchers’ objectives.

Table 1 GI-objectives

GI characteristic	Accompanying question
Extent	What is the extent of the geographical area for which this kind of research is conducted?
Scale and Resolution	At what geographical scale(s) are analyses for this research performed? Is it necessary to present the same type of information at multiple scale levels? Is the data available at an adequate resolution for producing the required information?
Geographically implicit vs. explicit	Is all information produced by this research geographically explicit or is it important to be able to present geographically implicit information too? Are all the data used for producing geographical information already explicitly linked to a location, or are techniques required to do so?
Georeferenced vs. vectorised	Is it important to produce objects from the data (vectorisation) or is it sufficient to link each feature to a location (georeferencing)?
Static vs. dynamic	Is the information fixed or are the location and/ or attributes subject to change?
Exploratory vs. explanatory	Is the information examined exploratory or is it necessary to conduct causal/ explanatory analysis?
2D vs. 3D	Is it sufficient to analyse and present information in a flat format or is it required to examine height/ depth values too?
Spatiotemporal	Is it important to have values at different (relative) time intervals for the same information in order to chart change of time and relate different periods relative to each other?

2.2. GI-Literacy

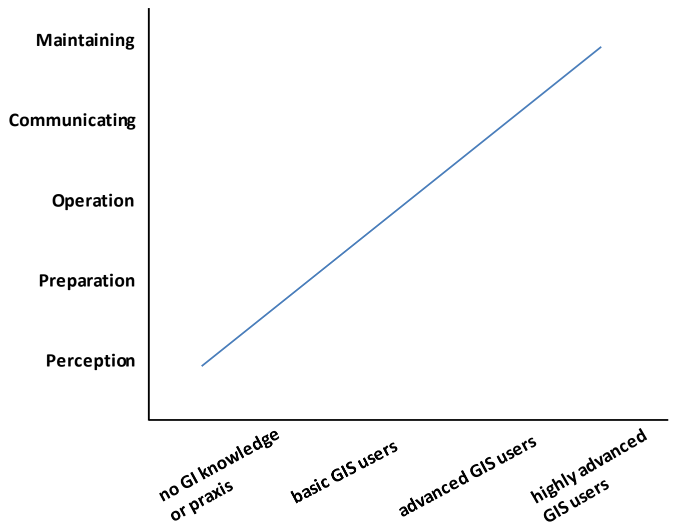
A framework for GI-literacy needs to address what abilities the different users in the target community have to produce the information and knowledge in order to meet their objectives. This assessment is informed by the users' objectives (are their GI-skills sufficient to produce the required information, based on data and information readily available to them?) and has implications for the technical and organisational architecture of the SDI (what components should be developed in order to support the users to produce the information given their GI skills?). In order to make GI-literacy a workable input for the SDI architecture, it is important to translate the unique GI-profile of each user into a recognisable GI-literacy level. To this end, we propose a model that confronts and combines the study on the conceptions of spatial information and information literacy as developed by Nazzari (2012) with the idea of a GI literacy scale. Nazzari developed a contextual model on information literacy for GI in the case of an online distance learning GIS programme. It comprised a framework with five stages that students and academics go through when facing a spatial challenge:

- Perception – the knowledge of the nature and characteristics of GI and being able to view it
- Preparation – the knowledge of capabilities, applications and limitations of GIS, allowing one to know how to make sense and use of GI and to diagnose knowledge and skill gaps
- Operation – knowing how to use GIS tools and techniques to make the GI meaningful and usable
- Communication – knowing ways of presenting and communicating solutions spatially to others
- Maintaining – knowledge of GI as a dynamic type of data that involves multiple disciplines and various temporal and spatial dimensions for which skills and knowledge need to be constantly updated

Nazzari´s framework can be connected to a 4-tiered scale of GI literacy – (1) no GI knowledge or praxis; (2) basic GIS users; (3) advanced GIS users; (4) highly advanced GIS users – in order to define generic user profiles. These profiles in turn, combined with the user objectives, inform which technical and organisational components of the SDI should be implemented. The relationship between the GI-literacy profiles and the technical components required is shown in figure 2. The more GI-literate the users are, the more emphasis there should be in the SDI architecture on components that facilitate sophisticated GI processing.

Whereas users with hardly any GI knowledge would need services with which they can view and find the spatial information in order to understand (perception/preparation) what geospatial technologies can offer, those with basic GIS knowledge would also want to download the spatial data in order to understand how a spatial analysis can be conducted (preparation/operation).

Figure 2 GI-literacy and stages in spatial challenges



2.3. SDI components

As identified by Hendriks et al (2012), many SDI definitions include users among the SDI components. This article, by contrast, treats the users separately and regards components as being solely organisational and technical in nature. To decide which components should be included in a specific SDI architecture, one should evaluate which of the technical and organisational SDI components would optimally support the users in their tasks.

To classify the existing components, different SDI definitions can be used (Hendriks et al 2012, Rajabifard et al 2002). Most definitions agree with the components identified by Masser in 1998: an SDI consists of data sets, agreements, standards, technology (hardware, software and electronic communication) and knowledge, which together provide a user with the geographic information needed to carry out a task. In contrast to Masser, we have related the user to knowledge, objectives and GI Skills. Furthermore, we are adding services as one of the SDI components. Although services can also be seen as part of technology, in our view services have become one of the main features with which a user centric SDI is to be developed and should therefore be approached as a separate component.

2.3.1. Technological components

Through services, an SDI enables users to share and exchange spatial data and information. The services formulated in the INSPIRE directive for a European SDI offer a clear classification: discovery, view, download, transformation and invoke services (Network Services Drafting Team 2008). In addition to these, we are adding upload services as they are vital for a user-centric SDI, enabling users to add content to the infrastructure.

<u>Discovery services</u> enable users to find and discover information. By enriching datasets with systematically formulated metadata about subject, keywords, category, the geographical extent, the projected coordinate system, date etc., the information can be part of an online catalogue or linked to other sources, thus being *found* by discovery services.

<u>Viewing services</u> enable users to view the geographic information. Protocols for two dimensional (and two and a half dimensional) viewing services have been formulated and developed (e.g. WMS), enabling users to access digital spatial information available through a server on a variety of clients. Three dimensional viewing services are currently being developed and will become an integral part of SDIs (Basanow et al 2008, Van Oosterom et al 2010). One of the biggest challenges for 3D GIS is that the datasets are very large and difficult to process on desktop computers. High performance cloud computing and database systems that handle big data will offer solutions (Van Oosterom et al 2010).

<u>Download services</u> enable users to download the information so they can edit or use spatial information in a local model download service. Downloading datasets is useful to deal with issues on the performance of viewing services. Having the data available offline makes GIS users less dependent on stable internet, which is useful during fieldwork.

<u>Transformation services</u> make it possible to combine datasets that are defined in different coordinate systems. Most desktop clients have transformation tools available. However, transformation services that enable different projected data to be interchangeable as viewing services will, especially for users with hardly any GI skills, be very useful.

<u>Invoke services</u> make it possible for the users to query datasets on the server, which generated dynamic outcomes. Invoke services are available through the web and offer a mean to invoke the linked spatial data services, thus dynamic access and query the spatial data (Lucchi and Millot 2009). Invoke services not only offer solutions to handle large datasets (facilitating cloud computing solutions), but also aid the development of custumised functionalities for specific user groups. Through invoke services, programmers in specific projects can develop Application Programming Interfaces (APIs) that make it possible to

develop custom made user functionalities for specific tasks on top of the SDI (e.g. City SDK, http://www.citysdk.eu/).

Upload services allow users to upload newly or edited information. At present, most SDIs do not include this service or offer it with major constraints. Legal issues and complex methods to upload newly produced information currently form a bottleneck in most SDI initiative. Developing easy-to-use, generic upload services will increase the user interaction and serve the users' needs.

Having discussed the different services as one of the components of an SDI, it must be emphasised that this component is closely related to the standards and the technology component. Standards in metadata facilitate discovery services; standards in data format facilitate viewing services; standards in projected coordinated systems facilitate data exchange between different projected coordinate systems; standards for the services themselves make SDI initiatives interoperable.

2.3.2. Organisational components

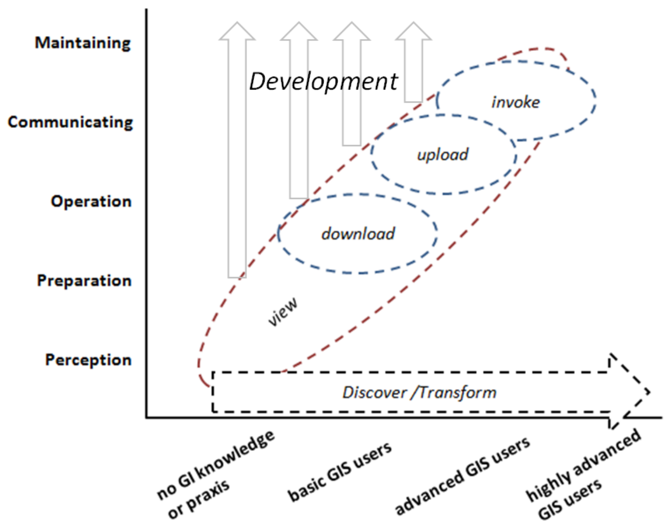
We have classified the datasets and legal issues as more organisational SDI components. The datasets are depend on the objectives of the users. How these are to be made available (through which service) are dependent on the users' GI literacy, but also legal issues. Although the tendency is to put data in the public domain (Kulk and Van Loenen 2012), data with restricted access will continue to be generated and require protection. Agreements on data usage are therefore part of and SDI. Datasets on, for example, unique not yet excavated archaeological sites, privacy sensitive information on architectural features hidden in residences or costly data that are made available for research purposes only are undesirable to be in the open domain. From a technological perspective this means that, to a certain extent, user access has to be controlled through registered accounts.

2.4. Framework for User centric SDI

The different elements discussed above together form the framework for a user centric SDI. The variety of objectives of the research community, combined with the GI literacy, together inform which organisational and technological components need to be implemented. As visualised in figure 3, the different elements influence each other strongly. The services encircled in the figure have to be interpreted as areas of focus. They do not imply that, for example, GI illiterate users do not use upload services. The ovals are placed to indicate where the emphasis of the SDI for the different users lies. Viewing, discovering and transformation services are considered to be used by all types of users, whereas download, upload and invoke are used by more experienced GIS users. This model connects invoke services to advanced and highly advanced users.

However, if the trend of developing APIs on invoke services which enables programmers to easily generate custom made tools continues, users with less GI knowledge will be able to use these services too.

Figure 3 visualisation on service and GI literacy confronted



To develop a user centric SDI, the first step is to implement this framework. Using it as a starting point for analysing the research community, the user will have to be constantly involved. The user objectives and functionality demands are dynamic and the development process should take account of this evolution.

3. A USER CENTRIC SDI FOR HISTORICAL AND HERITAGE LANDSCAPE RESEARCH

Within the scientific research of the history and heritage of the rural and urban European landscape three developments can be identified that have fostered the need for a user centric SDI. The first development is the spatial turn in historical and social sciences. Fundamental research of historical topics and heritage issues are increasingly viewed from a spatial perspective, with “landscape” as a prominent analytical concept. The need to reconstruct this landscape on a regional or national level by making a synthesis of information produced on a local scale can be seen as a trend in past oriented research (Arias and Warf 2009, Boonstra and Schuurman 2010, Van Manen et al. 2009, Wagtendonk et al 2009, Boonstra 2009, Schlögel 2003). To integrate different studies to produce a regional synthesis has led to the introduction of Geospatial technologies into these fields of research, which logically generated a need for these scholars to access and share geospatial information. The second change is that past oriented scholars are increasingly stimulated to valorise their research (Broek and Nijssen 2009). An important role for past oriented landscape researchers is to transfer their knowledge on past landscapes to society as part of our cultural heritage. The landscape is identified as an important medium for anchoring and storing both personal and social memories, and plays a vital role in how people identify with their living environment (Renes et al 2003, Duineveld 2006). The third development is a widening scope of disciplines that deal with the history and heritage of the landscape. (Lazrak et al 2012, Nijkamp 2012, Bosma and Kolen 2010). Heritage and history features are no longer exclusively studied by past-oriented scholars like archaeologists, art historians, historical geographers and historians, but have become an important source of information and inspiration for present and future oriented scientists like spatial economists, landscape architects and spatial planners.

The interest from other disciplines in the history and heritage of the landscape and the focus for past oriented scholars to valorise the research must be seen in light of a shifting heritage paradigm. Whereas the traditional approach to heritage was to solely conserve objects and sites through protection, the modern perspective on heritage is to incorporate heritage in the processes of transformation. The value and potential of heritage in the modern and future landscape is widely recognised and even part of national and European legislation (Valetta 1992, Florence 2000). A substantial part of the heritage sites will continue to be protected solely through conservation, but the "Protection through development" philosophy has been introduced as a modern, complementary perspective. The paradigm shift has encouraged disciplines with a long-standing interest in heritage, like history, art history and archaeology, and which previously acted as "the consciousness of authenticity", to complement their historical perspectives with future-oriented viewpoints (Bloemers 2010). This philosophy has attracted new disciplines to the study and management of heritage, notably those that assess and anticipate the dynamics of current and future landscapes, like urban planning, landscape architecture and spatial economics. (Van der Valk 2010, Lazrak et al 2012, Nijkamp 2012, Bosma and Kolen 2010).

The European scientific community is promoting collaboration between these different disciplines, through landscape research funding schemes that require cross disciplinary partnership (various FP7 calls). One of the major challenges for the resulting projects to succeed in letting past and future oriented landscape researchers make use of each other's insights by sharing data and information. The variety of research approaches, the differences in GI-literacy and the heterogeneity of data make the exchange of data and information challenging. Applying the framework presented in the first section of this article entails a thorough analysis of the landscape research resulting in a clear overview of the extent to which components are to be implemented based on the objectives and GI literacy of the users.

3.1. European landscape approaches

Dutch universities and other institutes conducting research (such as the Dutch Cultural Heritage Agency, RCE) have build up an impressive tradition in archaeological and historical landscape research, producing results of high academic standard, thereby achieving a leading position in the international research field (Bloemers 2010). Therefore, to analyse the heterogeneous European historical and heritage landscape research, Dutch landscape research has been used to identify three prominent European approaches. The first comprises fundamental research aimed at reconstructing the characteristics of (parts of) the landscape at a specific moment in time or in particular periods of its development. Examples of period specific landscape studies for the Dutch landscape are the Roman period (Van Londen 2006, Jeneson 2013), the early medieval period (Theuws 2007), or the 19th century (Van der Woud 2007). Most of these cross-sections, notably in landscape archaeology and historical geography, deal with the relationships and interactions between the natural landscape and human land-use.

The second landscape approach concerns fundamental research aimed at reconstructing the long-term development of (parts of) the landscape. It researches the long-term transformations in landscapes, viewing the landscape at each point in time as a complex interplay between mentalities and values, institutional and governmental changes, social and economic development, and ecological dynamics. The biography of the landscape refers to the continual passing on of the landscape from one 'owner' to the 'other', shifting from one social context to another and influencing successive generations of inhabitants (Spek and Elerie 2010, Kolen 2005, Renes et al 2013). Analyzing the landscape diachronically, scholars aim to identify and reconstruct dynamic processes of development and transformation.

The third landscape approach stands for the research of the present-day landscape where the past is being preserved, transmitted, remembered, valued and visualised. This approach includes research on the extent to which heritage is used in planning and policy, how heritage is researched for its economic use and attractiveness and studies on the socially contested nature of heritage. This landscape approach focuses on the concept of heritage and its meaning and value in current and future landscape. The approach is therefore labelled as "heritagescapes".

3.2. Cross-section of (Dutch) historical and heritage landscape research

To gain insight in the users' objectives and GI-literacy and what these imply for the desired SDI architecture, a cross-section of the Dutch landscape research is made. For each landscape approach presented above two representative use cases have been selected.

3.2.1. Period specific landscape approach

The use cases selected for the period specific approach are the *intersite Bandkeramik* settlement research and landscape archaeological research of the Roman villa world between Tongres and Cologne (Amkreutz et al 2012, Jeneson 2013). A short description of both studies is provided in table 2.

Table 2 Period specific landscape use cases

PERIOD SPECIFIC	**Title:**	**Exploring the Roman villa world between Tongres and Cologne : a landscape archaeological approach (Jeneson, 2013)**
	This study aims to reconstruct the rural world on the loess soils between the Tongres and Cologne in the Roman period. The main challenges for the reconstruction of this landscape, dominated by stone-built villas, were the highly dispersed and heterogenic datasets generated by almost a century of archaeological activities and how to spatially model uncertainty. Regarding the spatial component of the sites as well as the archaeological information, it was possible to reconstruct two scenarios. It is argued that the use of spatial dimensions is crucial to enable the reappraisal of different types of sites, other than settlement, resulting in a more accurate picture of the original composition and settlement density of these villa landscapes.	
	Title:	**Towards an infrastructure for intersite Bandkeramik settlement research (Amkreutz et al 2012)**
	To study the relationships in material and economic culture for the Linear Bandkeramik Pottery Culture (5250-4950 BC), there is an ongoing need for a complete analysis of the interaction and interrelationship between settlement and environment. Combining a complete inventory of published and unpublished bandkeramik sites with a paleo-environmental reconstruction of the landscape, enables scholars to gain insights to reconstruct the habitation of the landscape for this specific period. This research programme generates a digital dataset of archaeological activities and past environments that forms the basis for future landscape research.	

The two period specific use cases are characterised as synthesising studies. Both have collected archaeological records for a large geographical area and confronted these with reconstructions of the physical environment in order to understand and reconstruct past landscape dynamics. The archaeological records of both studies is characterised as heterogeneous and often unpublished. In order to perform spatial analysis both studies made a thorough, and time consuming, inventory of data to be collected and harmonised in terms of extent, resolution and coordinate system in order to be able to conduct comparative and relational analysis. Another important aspect is the dating of the different sites and features. Being able to study the time dimension is vital (Wagtendonk et al 2009). However, especially in the field of archaeology a lot of uncertainties in dating exist. Whereas some sites and features can be dated very precise, most of the features and sites are given a relative dating using constructs as *terminus post quem* (date after which) and *terminus ante quem* (date before which) or by being related to a period on an archaeological time scale. Being able to combine datasets with different temporal definitions is crucial research tool within the case studies presented. The environmental datasets used (e.g. paleo-geographical reconstructions, elevation models and soil maps) come from generic sources such as Alterra (Wageningen University) and TNO *Geologische Dienst Nederland* (GDN). Furthermore, it is important to notice that both studies go beyond the current national borders of the Netherlands. Studying past landscape goes often beyond current administrative borders (McKeague et al 2012).

The GI-literacy of researchers for both period specific use cases can be described as basic to advanced GIS users. Skills to prepare and organise collected datasets in order to conduct meaningful spatial analysis in specialised GIS software are present among the researchers (table 5 gives an overview of the implications on the services).

3.2.2. Use cases on “Landscape biographies” and long-term developments

To represent the "Landscape biographies” and long-term developments, the cultural biographical research of the Drentsche Aa National Landscape and the Zandstad region are selected (Spek and Elerie 2010, Bosma and Kolen 2010).

Instead of a specific period, culture or historical event, these use cases take the landscape itself as their starting point. Although both are classified as past-oriented approaches, they resulted in works aimed to be used by future oriented scholars and policymakers who intervene with the heritage of the landscape (Zandstad project: www.zandstad.nl; Drentsche Aa project: http://www.dorpsatlasdrentscheaa.nl/). The use cases have produced digital diachronic biographies of the landscape by combining reconstructions and insights from period specific research and extend these with historical sources that were partly made available in other initiatives (e.g. photographs, drawings, documents etc.). Although systematic research on the impact and added value of both digital biographies has not been conducted, some small scale experiments and initial results suggest the impact to be significant meaning that the digital biography approach is a useful tool (Burgers and van der Pijl 2010, Spek and Elerie 2010).

Table 3 Use cases on “Landscape biographies” and long-term developments

<table>
<tr><td rowspan="4">LONG TERM DEVELOPMENT</td><td>Title:</td><td>The Cultural biography of the Drentsche Aa National Landscape (Spek and Elerie 2010)</td></tr>
<tr><td colspan="2">During a five-year research action programme in the Drentsche Aa National Landscape, geologists, archaeologists, historical geographers, toponymists and ecologists put the theoretical concept of the cultural biography of landscape into practice at a regional practice. These different disciplinary researchers in this project have used a broad diversity of dataset, including interviews with residents resulting in valuable information about the toponyms. The biography of the Drentsche Aa resulted in an illustrated book and an online digital cultural atlas (www.drentscheaa.nl), which was used by spatial planners to develop this landscape taking the value of remains from the past into account.</td></tr>
<tr><td>Title:</td><td>The Biography of the Zandstad region (Bosma 2010)</td></tr>
<tr><td colspan="2">For the area around the Dutch city of Eindhoven (nicknamed "Zandstad"), the Zandstad project generated a digital biography (www.zandstad.nl). An interactive website in which information about crucial transformation moments over a time span of 3000 years is developed in order to research how planners, designers and heritage students could insert historical (economic) support in their planning and design repertory and integrate them in urbanisation plans for the immediate future via knowledge transfer with new media. Although the project is mainly aimed at future oriented scholars, the data it contains is the result of a long term development study.</td></tr>
</table>

To define the GI literacy for these use cases, a distinction must be made between the researchers that helped to produce the digital biographies and the end-users of idem. Both the Zandstad and the Drentsche Aa digital biographies are developed for landscape designers and a broader public and therefore have been designed as easy to use interfaces. The users were regarded to be non GI experts. The research teams that have developed these digital biographies can be classified as basic to advanced GIS users. They prepared the datasets available in the digital biographies by connecting, enriching and categorising existing data sources, producing new vector and raster data and presenting the datasets in a communication tool.

3.2.3. Use cases for the analysis of "heritagescapes"

The final category of studies differs from the biographical category in focusing on historical features in the present landscape rather than historical landscape transformation per se. The study on the economic value of cultural heritage and archaeological predictive modelling in Dutch Policy are selected as use cases for this heritagescape approach (Lazrak et al 2011, van Dommelen et al 2013, Kamermans, Van Leusen and Verhagen 2010).

Table 4: Use cases for the analysis of "heritagescapes"

HERITAGESCAPES	**Title:**	**The economic value of cultural heritage (Rietveld and Rouwendal 2009)**
	This research programme studies the economic value of cultural heritage. The influence of cultural heritage on property value, tourism, creative industry and the location choice of households was researched by using advanced spatial economical models. As indicators for cultural heritage, listed buildings, protected town and cityscapes and figures of museum visits were used. Research on the economic value of heritage is a rather new field of research and seen as an extra dimension besides the cultural historical value, experience and status of cultural heritage.	
	Title:	**Archaeological Predictive Modelling in Dutch policy (Kamermans, Van Leusen and Verhagen 2010)**
	Archaeological predictive modelling in Dutch policy is not to be seen as a single research programme or project, but as a widely performed activity in scientific and commercial research. Through a combination of different studies archaeologist developed predictive models with which they aim to reconstruct where past human activities took place. Besides gaining a better understanding of past dynamics, these predictive models are used in managing archaeological heritage. Although criticised by several academics, the intensity to which areas are researched is increasingly depending on the outcome of these models (Kamermans 2010).	

The study on the economic value of heritage reveals two important data issues. First, it indicates the importance of detailed and consistent documentation on the datasets. The indicators for cultural heritage used were listed state monuments and protected town and cityscapes together with figures on museum visits (Van Duijn and Rouwendal 2012, Lazrak 2011, Van Loon 2013). Using these indicators is not without problems. Understanding the quality of these datasets is crucial in interpreting the outcome of models used in spatial economics. The selection criteria of listed buildings, protected city- and townscapes have changed considerably over time, resulting in a heterogeneous dataset (van Koningsbruggen, Hellemondt 2010). Using these indicators in a spatial economical model should therefore be done with caution. Spatial economists are in this case very dependent on documentation generated by heritage experts. The second important aspect is that commercial and privacy-sensitive datasets were used (e.g. CBS-micro datasets, NVM data on house prices). Due to legal issues the extent to which they are allowed to publish figures on their analysis is limited. Many analyses are therefore presented in an aggregated form (Van Duijn et al 2012).

Another important aspect of the research conducted to value cultural heritage was the involvement of public partners. Workshops were organised in which researchers presented their research results to municipalities using a touch table to communicate the spatial information. Furthermore, an interactive web viewer is developed in which the research results are presented interactively (http://geoplaza.ubvu.vu.nl/cms/). This interactive webviewer is as communication tool to be used as a source of information on policy makers and the public.

The GI literacy for the spatial economists is indicated as advanced GIS users. Preparing datasets which enables to combine datasets collected on a different administrative scale is often performed (table 5 gives an overview of the implications on the services).

In Dutch landscape policy archaeological predictive maps are used to decide how intensive the archaeological landscape is to be researched when interventions take place. The quality of the models and the data therefore need to be well documented and scientifically profound. However, at the moment the diversity of the different models is very high. A coherent standard for archaeological predictive modelling does not yet exist (Verbruggen 2010), sometimes resulting in unlikely differences especially at the borders of research areas. Furthermore, the model outcomes are currently too much approached as static maps. Changes in the chances of finding archaeological sites based on new input or changing insights in archaeological predictive modelling currently have a minimal impact on the existing static maps used in policy.

Another aspect in predictive archaeological modelling is that the models themselves are getting more complex. With more data and more detailed data coming available, we predict that in time these models would have to use cloud computing technologies in order to be run.

The GI literacy of the researchers that generate archaeological predictive maps is very high. The researchers are able to combine large amounts of data and combine these into advanced models (table 5 gives an overview of the implications on the services).

3.3. Requirements European historical and heritage landscape SDI

Based on the cross section of Dutch historical and heritage landscape research, and making use of the analytical framework presented in section one the requirements for an initial SDI for this research community are extracted. The users' GI literacy and the objectives together determine the extent to which potential services are implemented.

General conclusions based on the cross section are that the research communities that study the history and heritage of landscape have a large variety of research approaches, resulting in a variety of research objectives. Furthermore the spectrum of GI literacy among Dutch landscape researchers identified in the different use cases is very wide. The landscape scholars differ from hardly having any knowledge on how to use geospatial tools to scholars that are considered to be highly advanced GI experts. Table 4 gives an overview of the users' GI literacy, objectives and the services needed for these approaches.

Table 5: GI literacy, objectives and services for history and heritage SDI

GI literacy	Examples based on cross-section	Description of tasks	Service Components
No GI knowledge or praxis	*Users of the Drentsche Aa and Zandstad digital biography; Landscape architects, spatial planners and the public. Participating municipalities for economic value of heritage project.*	*These users need to be able to find spatial data and be able to view this information and combine this information with other layers, which can have another projected coordinate system, on an interactive internet based map with basic webmapping functionality. Through invoke services, prepared by specialists, customised functionality can be added.*	Discovery, Viewing, Tool through Invoke and APIs
Basic SDI/ GIS users	*Archaeologists that study the relationship between a location and the environment. Spatial economists that generate thematic maps based on economic models.*	*These users need have access to reliable datasets which are well documented and findable through discovery services. In order to edit the information found these users need to be able to download it. After the data had been edited and new data has been produced based on archival research, these researchers need to upload their newly produced data in order to be reused in future research by other scholars.*	Discovery, Viewing, Download, Transformation, (Basic) Upload, Tool through Invoke and APIs
Advanced SDI/ GIS users	*Researchers that generate digital biographies to transfer knowledge to other stakeholders. The portal in which the information from the research on the economic value of heritage can be found.*	*Finding, viewing and downloading spatial information for these users are also considered to be essential functionalities. However, the main difference with Basic SDI users is that these users will also have to be able to create own webviewers for other audiences. Uploading new information and especially link with other data sources.*	Discovery, Viewing, Download, Transformation, Upload, Linking other data sources, Tool through Invoke and APIs
Highly advanced SDI/ GIS users	*Scholars who develop archaeological predictive maps combing qualitative research with quantitative models and that wish to develop dynamic models based on processing services*	*These users are highly advanced GIS experts for whom standard GIS desktop software are not powerful enough to execute spatial analysis. Developing services which provides dynamic archaeological maps would be highly advisable. Instead of producing a static result of the archaeological heritage, a dynamic service would provide an up to date and therefore better applicable tool for archaeological heritage management.*	Discovery, Viewing, Download, Transformation, Upload, Linking other data sources, Invoke

A few characteristics of the landscape research, derived from the cross section, stand out. First, in interdisciplinary research there is an urgent need for high quality metadata for finding reliable data and information and judging its usefulness. Second, users will have to be able to download and upload the data in order to edit or use in a local GIS and to upload newly or edited data. Thirdly, user accounts need to be generated in order to deal with legal issues on data usage and privacy sensitive information. Fourthly, a clear trend can be noticed that project specific interactive web mapping viewers are created as communication tools for sharing knowledge for analytical and valorisation purposes. Especially the biographical approaches benefit from interactive webviewers. The use cases presented have put much effort in generating viewers, a trend that is also seen in many other initiatives for the Netherlands (examples can be found here: http://www.den.nl/projecten). Fifthly, these initiatives requires connections with digital archives for which individual objects are enriched with an exact locations and included in the viewer are vital. And, finally, capabilities to query datasets online are needed to dynamically apply models and cloud computing capabilities to deal with complex models and large datasets.

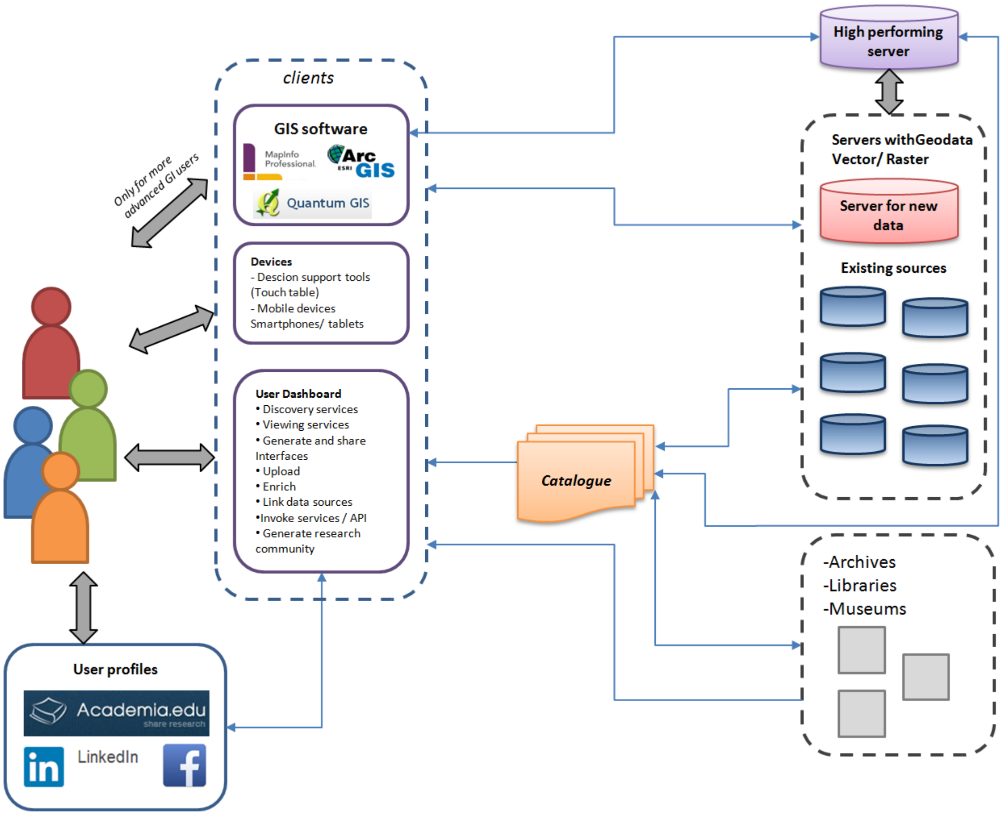
4. ARCHITECTURE FOR THE SDI FOR THE SCIENTIFIC RESEARCH OF THE HISTORY AND HERITAGE OF THE DUTCH URBAN AND RURAL LANDSCAPE

The initial architecture for the SDI for the historical and heritage landscape research is discussed in three steps. Based on the analysis of the communities´ objectives and GI literacy which resulted in required components, first a conceptual architecture for the user centric SDI is presented. Second, this conceptual architecture is translated into a technical architecture. Finally, these two combined inform a discussion of the SDI from an organisational point of view.

4.1. The conceptual architecture of the infrastructure

Besides the conventional SDI requirements like a catalogue and interoperable services to different clients, the historical and heritage landscape SDI needs to be an environment in which scholars can easily create and develop their own interfaces for communicating with other scholars and non academic stakeholders. There is a great need for users to be able to create project-based map viewing interfaces in which newly produced datasets can be combined with existing spatial information and in which digital archives can be projected by using points of interest as linkages. Improving these interfaces with API toolboxes based on invoke services will allow the creation of customised user functionalities. This will in turn allow landscape scholars to improve the communication of the research projects for academic and valorisation purposes.

Figure 5 Conceptual architecture landscape research



The main part of the architecture of the infrastructure is a user dashboard (figure 5). This dashboard allows users to find and download available data, but also to upload newly produced information easily and generate map interfaces in which viewing services from different sources, with variable projected coordinate systems, can be combined. An important feature of this mapview creating feature is that it can be enriched with points of interest that link to digital not yet spatially explicit archives. Tools in the dashboard will be open without a login, however, in order to store views and to deal with legal issues, users can subscribe for an account. Connecting the accounts to professional or social media network such as Academia.edu, LinkedIn, Facebook allows users to integrate existing research networks and communities to their professional SDI activities.

The demand for dealing with complex models and dynamic services within landscape research is especially approached from a technological perspective. These scholars are considered highly advanced GI users and capable of dealing with complex protocols to process the data. Yet, the main problem is that landscape researchers do not have access to high performing servers that can actually handle these demands. A server with high processing capabilities should make it possible for these scholars to develop and run complex models dynamically.

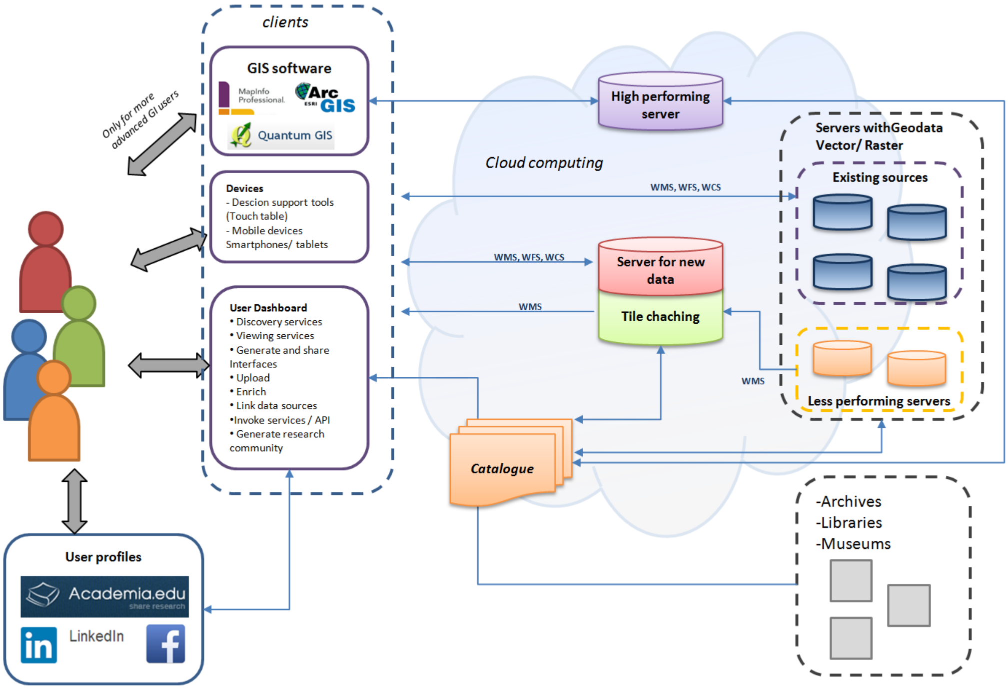
4.2. Technological implications on the architecture of the SDI

In translating the conceptual design of the architecture to a working technical infrastructure, we can build on various existing and well documented services, technologies and standards resulting from two decades of SDI development (Nebert 2009, Network Services Drafting Team 2008, http://www.opengeospatial.org/). Placing the user in the centre of the SDI requires in particular enhancements in the performance and interface of the proposed dashboard. These two aspects are vital for the success of an SDI initiative, yet have often been underestimated. When users have to wait too long to get the requested spatial information, or when the interfaces and functionalities are too difficult to grasp, they are not willing to continue using the SDI. The performance of the infrastructure can be optimised by using cloud computing capabilities and tile caching techniques. One of the main advantages of making use of cloud computing services is that the performances of the servers are scalable. When needed, the capabilities of the servers can be maximised to deal with a high demand optimising the response rate. For large datasets that are queried often, tile caching techniques are available. As identified by Loechel and Schmid (2013), a large variety of tile caching techniques exists and is constantly evolving to be faster and robust. To not be dependent on the technical performance of other servers, tile caching capabilities are placed in between the external server and the user. This enables WMS caching from other, less performing, servers, thus optimising the user experience. The user dashboard will be decisive for the success of the SDI initiative. The functionalities to find, download, upload and create viewing interfaces that can be embedded in project websites have to be high performing and user friendly. Technological developments to improve these functionalities in the user dashboard are one of the key elements that will convince users to actually use the SDI tools that are built. The development of the user dashboard should be approached cyclical in close collaboration with the user community and usability experts of web interfaces.

In the technical architecture of (figure 6), the servers that provide mapping services make use of cloud computing services. This requires less skill from the technical developers regarding server security, thus requiring less maintenance.

It also enables dealing with peak loads. By monitoring data usage, the server capabilities for specific datasets can be optimised to meet high demands. Peak loads as a consequence of publicity on the publication of the datasets can thus be handled by extending the server capabilities to the expected number of hits.

Figure 6 Technological implications on the architecture



4.3. Organisational architecture

From an organisational perspective, the requirements for a successful SDI are twofold. First, a party coordinative institute has to take the leadership and ensure long term viability. Second, the users have to be closely involved in order to ensure that the needs of the users are constantly monitored and taken care of. Implementing an SDI requires a strong coordination and leadership (Craglia and Annoni 2007). However, this should not be done primary top down but some institution needs to be responsible. For the Dutch landscape research parties that would be suitable would be the University Libraries in close collaboration with Cultural Heritage Agency (RCE) and data initiatives as Digital Archiving and Networked Systems (DANS). Involving partners that have experience and are willing to think about the long term of the infrastructure is vital for any SDI initiative to survive on the long term. To keep a track on the user involvement more effort is to be put “in building and maintaining social networks, understanding needs and evaluating social impacts, and delivering results which demonstrably add value to both operational and strategic activities of heterogeneous user groups with often conflicting objectives” (Craglia and Annoni 2007). Thus, generate the necessary organisational support and placing the user requirements at the heart of the developing process.

4.4. Implementation Architecture

For the development of the SDI for the history and heritage of the urban and rural landscape, the user is placed at the heart of the developing process. Starting by analysing existing use cases has provided valuable information for the architecture of historical and heritage landscape research from a user perspective. The architecture as discussed above is implemented according to the requirements of the landscape research as part of the VU Geoplaza (http://geoplaza.ubvu.vu.nl/cms/nl/) developed as research SDI by the Spatial Information laboratory and University Library, both VU University Amsterdam. Parts of the architecture are developed and completed, however in some cases fine tuning is required. Effort is put in the optimizing the technical functionality of the viewing services and building blocks have been developed for the user dashboard. By applying the “think-play-do” approach as formulated by Dodgson, Gann and Salter (2005) and developing the SDI cyclically, the developing process of the heritage and history SDI keeps the user requirements in sight. The approach formulated by Dodgson, Gann and Salter states that innovation can be achieved by first a phase of thinking about options and creating new ideas, then playing with them to see if they are practical, economical and marketable, and finally doing by implementing the innovation. Several waves follow up on each other in which the developers are regularly provided with the user requirements. To implement these waves, new projects in this research domain are currently testing the SDI functionality and formulating development needs, in close collaboration with the SDI developers.

5. CONCLUSIONS

This article has outlined and implemented a methodological framework for the development of a user centric SDI. By analysing the users' GI-literacy and objectives it produced insight in the extent to which SDI components have to be implemented. Based on this analysis a conceptual and technical architecture for a user centric SDI is designed. In this first stage, the SDI experts played a coordinating role but extensively consulted researchers in the domain of historical and heritage landscape research and policy to systematically determine their needs. In the next stage, new research projects will test the initial SDI services and collaborate with the SDI developers to enhance the infrastructure.

The variety in GI literacy and objectives of the heterogeneous interdisciplinary landscape research community made the study presented in this article a good example for third generation SDI development. The implications of the users' needs on the extent to which the SDI components need to be implemented applied on this research community are illustrative for third generation SDIs.

By analysing the research community that studies the history and heritage of urban and rural landscapes this article generates a clear view on how to develop a SDI for this research community and how to approach the development of third generation SDIs in general. The use cases presented demonstrate that this research community would highly benefit from a user centric SDI. An SDI would foster the needs of past and future oriented landscape scholars to find data and information which at the moment is stored by the individual researchers, research units, institutions and organisations and which is often difficult to access. Organising the data and information sources and making the findable through discovery services is considered to be fundamental for future research. However, the biggest innovation for this research community is that the architecture presented enables them to easily generate viewers, that it enables them to implement dynamic services and that complex models can be run making use of cloud computing. These innovations will foster innovative landscape interdisciplinary research by helping to understand and reconstruct past landscape dynamics, enable both past and future oriented scholars to exchange information about the landscape and enable past oriented scholars to valorise their research.

One of the main focuses in the architecture of the user centric SDI presented is the user dashboard. The dashboard will be the starting point for most users. The interface of this dashboard has to be clear and user friendly, an aspect which many SDI initiatives have failed to produce. Developing this interface has to be an iterative process in order to keep a constant track on the users' needs and demands. Besides the interface of the dashboard the performance of the services offered in the SDI has to be very good. Getting the information fast to the users' client is a key component of a user centric SDI in order to stimulate users to return.

6. FUTURE DIRECTIONS FOR USER CENTRIC EUROPEAN LANDSCAPE SDI

The potential of offering easy-to-use tools which enables users, especially for the landscape research community, to generate viewers and develop functionalities based on the data and information available is very high. The technological step which therefore has to be taken is to develop more generic APIs which enables "newcomers" in the fields of Geospatial technologies to develop functionalities on top of the well known SDI-services that have been developed in the last decades.

Furthermore there are two developments which are to be signalled in the field of landscape research for which generic services are needed. The first one is the trend to involve the crowd to participate to generate new information (Goodchild, 2007). Especially in the fields of history and heritage a groups of hobbyists/ volunteers are willing to digitise historical information (e.g. http://www.velehanden.nl, a system in which archives are transcribed by volunteers). Volunteered Geographic Information (VGI) have a large potential in SDIs for historical and heritage landscape research. The Drentsche Aa case study presented has some basic functionality. However, we believe that making VGI functionalities for landscape researchers available through the dashboard would be useful to generate new information but also generate societal involvement. The second development for which services will have to be developed is to store, view and invoke big spatial data sets. Within the fields of history and heritage the tendency is to produce 3D representations and reconstructions of specific objects or whole landscapes (http://v-must.net/). 3D-services with which the datasets can be used are to be developed and are considered to be a future component of the SDI services.

The article has given a clear methodological framework on how to develop a third generation user centric SDI. This resulted in a clear architecture that is not only valuable for the research community that studies the history and heritage of European landscape, but also exemplary for other third generation SDIs.

7. ACKNOWLEDGEMENTS

The analysis of the different landscape research approaches and architecture for a user centric SDI presented in this article are developed as a result of the NWO funded Integrating Heritage project (file: 380-57-001). The aim of the Integrating Heritage project was to study the needs of an SDI for historical and heritage landscape research. This study resulted in the "Rediscovering Landscape" research programme (http://www.rediscoveringlandscape.nl), an interdisciplinary collaboration between the Spatial Information laboratory (SPINlab), the Research institute for the heritage and history of the Cultural Landscape and Urban Environment (CLUE) and the University library of the VU University Amsterdam. The architecture presented is partly implemented under the flag of the VU Geoplaza project (http://geoplaza.ubvu.vu.nl/cms/nl/). The authors wish to thank Peter Vos for the technical development and implementation of (parts) of the architecture presented. A second research programme, SDI4URD (Spatial Data Infrastructure for Urban Regions in the Delta) has been executed parallel to the development of the architecture of Rediscovering Landscape. The authors wish to thank project leader Simeon Nedkov for his valuable input on the conceptual and technical architecture presented in this article.

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